

Al ant  
specific changes to genes encoding particular enzymes (see, for example, Cortes *et al.*, Science 268:1487, 1995; Kao *et al.*, J. Am. Chem. Soc. 117:9105, 1995; Donadio *et al.*, Science 252:675, 1991; WO 93/1363; U.S. Patent Number 5,824,513; WO 98/49315; U.S. Patent Number 5,652,116; U.S. Patent Number 5,824,774; WO 98/51695; U.S. Patent number 5,795,738; and WO 98/01546). The hope is that, by modifying the gene encoding the synthetic enzyme, the researchers will be able to generate new enzymes with altered synthetic characteristics, which new enzymes will in turn generate new chemical compounds that are related to those produced by the naturally-occurring enzymes, and therefore are likely to have similar desirable biological activities.

2) Please replace the paragraph starting on page 2 line 10 and ending on page 2 line 27 with the following amended paragraph:

02  
Concurrently, several groups have also been interested in generating combinatorial libraries of compounds synthesized using novel synthetic methods. Specifically, in many cases, researchers have developed "biased" libraries, in which all members share a particular characteristic, such as an ability to interact with a particular target ligand, or a characteristic structural feature designed to mimic a particular aspect of a class of natural compounds. For example, a number of libraries have been designed to mimic one or more features of natural peptides. Such "peptidomimetic" libraries include phthalimido libraries (WO 97/22594), thiophene libraries (WO 97/40034), benzodiazopene libraries (US 5, 288, 514), libraries formed by the sequential reaction of dienes (WO 96/03424), thiazolidinone libraries, libraries of metathiazanones and their derivatives (US 5,549,974), and azatide libraries (WO 97/35199) (for review of peptidomimetic technologies, see Gante, J., Angew. Chem. Int. Ed. Engl. 1994, 33, 1699-1720 and references cited therein). Each of these libraries has provided solid phase synthetic strategies for compounds possessing specific core functionalities, but none achieves the complexity of structure found in natural products, or in other lead compounds prepared through traditional chemical synthetic routes. Complex natural products commonly contain several different functionalities and often are rich in stereochemical complexity. Such diversity and

Q2 cont  
complexity is difficult to achieve if the synthesis is restricted to compounds containing a specific core functionality.

L 3) Please replace the paragraph starting on page 3 line 31 and ending on page 3 line 32 with the following amended paragraph: S

Q3  
Figure 1 depicts the biosynthesis of several erythromycin derivatives using several different starter units.

L 4) Please replace the paragraph starting on page 4 line 14 and ending on page 4 line 29 with the following amended paragraph: S

Q4  
Recognizing the desirability of utilizing both the efficient and powerful methods of natural products biosynthesis and the diverse repertoire of reactions available in synthetic organic chemistry, a method for merging combinatorial biosynthesis incorporated above with techniques of synthetic organic chemistry is provided. In general, this method, combinatorial biology, involves 1) providing "starter units", wherein the starter units are capable of being accepted by the modular biosynthetic enzymatic machinery, and have incorporated therein a "functional handle" capable of reacting with specific functionality present on a solid support; 2) feeding these "starter units" into the modular biosynthetic enzymatic machinery, in vivo or in vitro, to obtain complex template molecules; and 3) further functionalizing the complex template molecules using synthetic organic chemistry to provide a collection of complex "unnatural" natural products having structural, topological, stereochemical and functional diversity. As used herein, the term "starter unit" comprises any compound that can be incorporated into the biosynthetic pathway. For example, certain biosynthetic enzymes, such as polyketide synthases, utilize two different classes of "starter units", specifically "initiator" molecules and "extender" molecules, typically acetates or propionates. For the purposes of the present invention, either category, "initiator" or "extender" qualifies as a "starter" molecule.

5) Please replace the paragraph starting on page 4 line 30 and ending on page 5 line 17

with the following amended paragraph:

05  
As one of ordinary skill in the art will realize, because the starter units have incorporated therein a functional handle, they, or any of the products generated from these starter units, are capable of being attached to solid support units at any stage in the combinatorial biosynthetic pathway. In one preferred embodiment, the starter units are attached to solid support units prior to feeding the starter units into the modular biosynthetic enzymatic machinery, and thus the support bound starter units are fed into the biosynthetic enzymatic machinery to generate a collection of complex template structures. These template structures thus generated can then be further functionalized using synthetic organic chemistry, or can be further functionalized using any combination of synthetic organic chemistry and reintroduction into the biosynthetic enzymatic machinery. In another preferred embodiment, the starter units are fed to the modular biosynthetic enzymatic machinery prior to being attached to the solid support, and thus template structures are generated. In particularly preferred embodiments specific functionalities can also be incorporated into the template structures via the original starter unit capable of being recognized by an antibody and then purified. Alternatively or additionally, these templates can then be attached to solid support units and further functionalized using synthetic organic chemistry or any combination of synthetic organic chemistry and the biosynthetic enzymatic machinery.

6) Please replace the paragraph starting on page 5 line 18 and ending on page 5 line 23 with the following amended paragraph:

06  
Thus, the present invention represents a broadening of the concept of combinatorial biosynthesis to incorporate the advantages of organic synthetic techniques on the solid phase to generate increasingly complex "unnatural" natural products. Various characteristics of the starter units and the reactions utilized in preferred embodiments of the present invention are discussed in more detail below; certain examples of the method of the present invention are also presented.

7) Please replace the paragraph starting on page 6 line 8 and ending on page 6 line 19 with the following amended paragraph:

07 Alternatively, as mentioned above, various researchers have made modifications to certain preferred biosynthetic enzymes that alter their catalytic properties (see, for example, Cortes *et al.*, *Science* 268:1487, 1995; Kao *et al.*, *J. Am. Chem. Soc.* 117:9105, 1995; Donadio *et al.*, *Science* 252:675, 1991; WO 93/1363; U.S. Patent Number 5,824,513; WO 98/49315; U.S. Patent Number 5,652,116; U.S. Patent Number 5,824,774; WO 98/51695; U.S. Patent number 5,795,738; and WO 98/01546 ). Moreover, United States Patent Application Serial Number 09/225,990, entitled "Improved DNA Cloning", filed on even date herewith and incorporated herein by reference, describes a powerful system for the production of modified versions of biosynthetic enzymes, and in particular for the production of libraries of modified enzymes. Preferred embodiments of the present invention utilize such modified enzymes, and preferably libraries of modified enzymes, to catalyze synthetic reactions with inventive starter molecules.

8) Please replace the paragraph starting on page 6 line 31 and ending on page 7 line 19 with the following amended paragraph:

08 As discussed above, the method of the present invention utilizes any combination of enzymatic machinery that can be employed for specific classes of biosynthetic reaction pathways. In determining the specific "starter units" that will be utilized in the synthesis, consideration must also be made to the desired biosynthetic pathway to employ, and thus a desired family of compounds to be synthesized. For example, specific biosynthetic pathways such as polyketide synthases and peptide synthases, utilize particular starter units known to be accepted by the modular enzymes to produce a variety of natural products. In but one example, carboxylic acid building blocks having differing functional moieties such as methyl, ethyl, propyl groups are utilized by modular polyketide synthases to yield topologically, functionally and stereochemically diverse structures such as 6-deoxyerythronolide B and tylactone (see, Khosla, *Chem. Rev.* **1997**, 97, 2577). Similarly, as shown in Figure 1, functionalized thioesters are utilized to generate a series of derivatives having structures similar to erythromycin (see,

OS  
ant

Khosla, *Chem. Rev.* **1997**, 97, 2577). As one of ordinary skill in the art will realize, the modular enzymes that are produced by the shuffling may not result in the ability to predict the specific starter units that will be incorporated into the enzymatic machinery. Thus, the ability of a desired or random set of starter units to become attached to the solid support and subsequently diversified using combinatorial techniques (split-pool synthesis) becomes particularly important in identifying *functional* starter units.

9) Please replace the paragraph starting on page 7 line 20 and ending on page 7 line 32 with the following amended paragraph:

09

Clearly, as mentioned, each of the starter units provided must be capable of being accepted by the enzymes "machinery", and thus the functionality and structural topology must be compatible with the biosynthetic pathway. In but one example, as shown in Figure 2, it would be desirable for a terpene-based pathway to utilize functionalized derivatives of a farnasyl pyrophosphate analog. Additionally, for an amino-acid based pathway (peptide synthases), it would be desirable to utilize functionalized derivatives of amino acids. Figure 2 additionally provides a collection of suitable "starter units" classified according to their utility in a specific biosynthetic pathway. Furthermore, these units can be derivatized and combinatorialized at a stage prior to feeding the units into the enzymatic machinery to produce structures having more diverse functionalities, or to produce structures having more complex topology. Thus, any structure may be utilized as a "starter unit", regardless of the complexity and functional diversity of the compound, provided that the starter unit is capable of being utilized by the enzymatic pathway.

10) Please replace the paragraph starting on page 8 line 26 and ending on page 9 line 15 with the following amended paragraph:

010

An additional important matter to take into consideration when utilizing a starter unit having "handles", is the number of "handles" that will ultimately be incorporated into the complex template as a result of the biosynthesis. For example, if a simpler (less structurally

complex) starter unit is utilized (for example one that is used in successive condensation reactions, as exemplified in the polyketide synthases) a larger number of handles will be incorporated. Thus, if one were to incorporate a handle into a starter unit that is utilized in successive "rounds" by the enzymatic machinery, a template structure would result having many handles incorporated therein. Thus, to overcome this problem, it is preferable to 1) utilize starter units that are only incorporated once, as depicted in Figures 2 and 3 by the use of the aryl functionality, and as may be dictated by the selectivity of specific reactions in the enzymatic pathway; 2) to incorporate the handle into a limited number of starter units (for example, one or two units) involved in the synthesis, or 3) to utilize more complex starter units, as depicted in Figure 2, for the polyketide pathway, and thus the enzymatic machinery does not need to utilize as many of the starter units and therefore fewer handles will be incorporated. As one of ordinary skill in the art will realize, when selecting specific starters it is necessary to take into consideration the specific enzymatic biosynthetic pathway to be utilized (and the specificity of incorporation of certain starters) and the number of "handles" desired in the resulting template structure. Once the "handles" have been incorporated into the "starter units", the starter units can either be fed directly into the enzymatic machinery or coupled directly to the solid support.

11) Please replace the paragraph starting on page 9 line 16 and ending on page 9 line 29 with the following amended paragraph:

Whether the starter unit or the template structure is utilized for coupling to the solid support, (which, as one of ordinary skill in the art will realize, also has an alkyne, or other desirable functionality, bound thereto via a cleavable bond utilizing standard synthetic organic techniques) the two alkynes incorporated can then be coupled, in a preferred embodiment, using a Glaser Coupling reaction. Specifically, in this reaction, the addition of copper (II) acetate to the reaction medium effects coupling of the two components to yield a solid support having bound thereto a starter unit, or a template structure, via a diyne functionality. In other exemplary embodiments, suitable functional handles which can also be easily incorporated into starter units and solid support units using standard techniques of synthetic organic chemistry, include olefins

all and  
and iodoalkenes. Thus, coupling of the components can be effected using olefin metathesis and Stille Coupling reactions, respectively. One of ordinary skill in the art will realize that although the abovementioned functionalities are particularly preferred, other functionalities that will not interfere with, or be altered by, the chemistry being employed by the enzymatic modular machinery may also be utilized.

2 12) Please replace the paragraph starting on page 10 line 17 and ending on page 10 line 25 with the following amended paragraph:

all 2  
In one particularly preferred embodiment, as shown by pathway A, the selected starter units having the functional handles incorporated therein can be fed directly into the mutated biosynthetic enzymatic machinery. Thus, after exposure to the enzymatic machinery, a unique template compound can be obtained and at this stage can be purified, preferably using an antibody recognition element, or can also be attached to a solid support unit. Subsequently, after attachment to a solid support unit, the template could be reintroduced into the enzymatic machinery (same or different) to thus obtain a modified template. Alternatively, and/or additionally, the template could be utilized in split-pool organic synthesis to generate combinatorial libraries of complex "unnatural" natural products.

2 13) Please replace the paragraph starting on page 11 line 10 and ending on page 11 line 19 with the following amended paragraph:

all 3  
Referring to the embodiments discussed above, either split-pool or parallel synthesis methods can be employed at each stage of the inventive method to provide a desired collection of compounds. For example, if the starter unit is not initially attached to the solid support a parallel synthesis technique is preferably utilized so that the product resulting from the enzymatic machinery can be identified using spatial encoding methods. Additionally, subsequent identification of compounds using standard methods such as nuclear magnetic resonance spectroscopy or mass spectrometry can also be employed to identify specific compounds. Depending on the size of the library of compounds desired for the synthesis, the identification of

913  
cont  
individual compounds may be prohibitively time consuming and therefore a spatial encoding method may be more particularly preferred.

2  
14) Please replace the paragraph starting on page 11 line 29 and ending on page 12 line 23 with the following amended paragraph:

014  
In another more particularly preferred embodiment of the present invention, a solid phase synthesis technique is utilized for the biosynthesis of the templates and the diversified structures, or alternatively for the synthesis of the diversified structures produced from template structures generated in solution as described above. As discussed in detail, the starter units or the template structures are attached to the solid phase directly or through a linking unit, depending on the stage of the procedure a solid phase synthesis is desired. Advantages of solid phase techniques, most particularly at the stage when the template structures are functionalized using synthetic organic techniques, include the ability to more easily conduct multi-step reactions and the ability to drive reactions to completion because excess reagents can be utilized and the unreacted reagent washed away. Perhaps one of the most significant advantages of solid phase synthesis is the ability to use a technique called "split and pool", in addition to the parallel synthesis technique, developed by Furka. (Furka *et al.*, *Abstr. 14th Int. Congr. Biochem.*, Prague, Czechoslovakia, 1988, 5, 47; Furka *et al.*, *Int. J. Pept. Protein Res.* 1991, 37, 487; Sebestyen *et al.*, *Bioorg. Med. Chem. Lett.*, 1993, 3, 413.) In this technique, a mixture of related compounds can be made in the same reaction vessel, thus substantially reducing the number of containers required for the synthesis of very large libraries, such as those containing as many as or more than one million library members. As an example, the solid support templates or starter units can be divided into  $n$  vessels, where  $n$  represents the number species of reagent A, or the number of different biosynthetic pathways created by the shuffling procedure, to be reacted with the template structures or starter units. After reaction, the contents from  $n$  vessels are combined and then split into  $m$  vessels, where  $m$  represents the number of species of reagent B, or the number of different biosynthetic pathways created by the shuffling procedure, to be reacted with the scaffold

0214  
cont

structures. This procedure is repeated until a desired collection of structures is obtained to yield a library of "unnatural" natural products.

15) Please replace the paragraph starting on page 12 line 24 and ending on page 13 line 6 with the following amended paragraph:

015

The use of solid phase techniques in the present invention may also include the use of a specific encoding technique. Specific encoding techniques have been reviewed by Czarnik. (Czarnik, A.W., *Current Opinion in Chemical Biology*, 1997, 1, 60.) As used in the present invention, an encoding technique involves the use of a particular "identifying agent" attached to the solid support, which enables the determination of the structure of a specific library member without reference to its spatial coordinates. One of ordinary skill in the art will also realize that if smaller solid phase libraries are generated in specific reaction wells, such as 96 well plates, or on plastic pins, the reaction history of these library members may also be identified by their spatial coordinates in the particular plate, and thus are spatially encoded. It is most preferred, however for large combinatorial libraries, to use an alternative encoding technique to record the specific reaction history.

16) Please replace the paragraph starting on page 13 line 7 and ending on page 13 line 19 with the following amended paragraph:

016

Examples of particularly preferred alternative encoding techniques that can be utilized in the present invention include, but are not limited to, spatial encoding techniques, graphical encoding techniques, including the "tea bag" method, chemical encoding methods, and spectrophotometric encoding methods. Spatial encoding refers to recording a reaction's history based on its location. Graphical encoding techniques involve the coding of each synthesis platform to permit the generation of a relational database. Examples of preferred spectrophotometric encoding methods include the use of mass spectroscopy, fluorescence emission, and nuclear magnetic resonance spectroscopy. In a most preferred embodiment, chemical encoding methods are utilized, which uses the structure of the reaction product to code

016 cont  
for its identity. Decoding using this method can be performed on the solid phase or off of the solid phase. One of ordinary skill in the art will realize that the particular encoding method to be used in the present invention must be selected based upon the number of library members desired, and the reaction chemistry employed.

---

17) Please replace the paragraph starting on page 13 line 20 and ending on page 13 line 26 with the following amended paragraph:

---

017  
Subsequent characterization of the library members, which can include either the scaffolds obtained after the biosynthetic pathway or the complex molecules obtained after diversification using synthetic organic chemistry, can be performed using standard analytical techniques, such as mass spectrometry, Nuclear Magnetic Resonance Spectroscopy, and gas chromatography. One of ordinary skill in the art will realize that the selection of a particular analytical technique will depend upon whether the inventive library members are in the solution phase or on the solid phase.

---

18) Please replace the paragraph starting on page 14 line 8 and ending on page 14 line 27 with the following amended paragraph:

---

018  
Figure 5 depicts specific natural products which are capable of being generated using the method of the present invention, or alternatively derivatives of which are also capable of being generated using the method of the present invention. Specifically, these structures exemplify the variety of sites of latent functionality at which diversification can be achieved using synthetic combinatorial techniques. As discussed previously, this can be achieved using solution or solid phase methods, using parallel or split-pool techniques. It is particularly preferred, however, to utilize solid phase split-pool techniques. Examples of specific reactions to which some or all of the systems depicted in Figure 5 can be subjected to in solution or on the solid support include, but are not limited to, i) addition of nucleophiles (such as primary and secondary amines), ii) functionalization of free hydroxyls with electrophiles (for examples isocyanates, anhydrides, or acid chlorides, iii) opening of epoxides with nucleophiles, such as amines, under ytterbium

ais and  
catalysis, iv) functionalization of aromatic rings, specifically functionalization at an aryl iodide by conversion to such structures as amines, amides, aromatic rings, alkenes, alkynes, and heterocycles using palladium catalyzed chemistry such as Buchwald-Hartwig aminations, Heck and Stille couplings, Sonogashira/Castro-Stephens couplings, Suzuki and Stille couplings, and carbonylations. Furthermore, resulting aryl alkynes can undergo rhodium-catalyzed hydroacylation and azide cycloaddition and nitron and nitrile oxide cycloadditions. Other examples of diversification reactions at potential sites include reactions at amines and amides. For example, amides may be functionalized using a Mitsunobu reaction to generate alcohols such as straight chain, branched, and cyclic alcohols.

L 19) Please replace the paragraph starting on page 14 line 31 and ending on page 15 line 17 with the following amended paragraph:

019  
One of ordinary skill in the art will realize that the above examples are representative of the reactions that can be used to diversify not only the templates, but also the starter units, of the present invention and are not intended to be exclusive. Rather, all equivalents thereof are intended to be within the scope of the presently claimed invention. A skilled artisan in the field of synthetic organic chemistry will be able to readily identify those reagents capable of reacting to create further diversity at selected sites in the inventive template structures and starter units to generate compounds and libraries of compounds reminiscent of natural products. The inventive method is particularly useful for the generation of such compounds because it incorporates the efficiency and creativity of a method for manipulating the enzymatic reactions that produce such complex structures in nature with the arsenal of reactions available using synthetic organic techniques. For example, the generation of complex templates can be difficult utilizing only synthetic organic techniques, however, nature efficiently and elegantly provides these templates. Combining this with synthetic organic chemistry enables the use of reactions, such as palladium catalyzed reactions, that are not available in nature and thus the best of both systems can be utilized to generate compounds having unprecedented structural, topological, stereochemical and functional diversity.

20) Please replace the paragraph starting on page 15 line 28 and ending on page 16 line 13 with the following amended paragraph:

020 In a particularly preferred embodiment of the invention, one or more inventive compounds is contacted with a biological target having a detectable biochemical activity. Such biological targets include, for example, enzymes, receptors, subunits involved in the formation of multimeric complexes. Such multimeric complex subunits may be characterized by catalytic capabilities (such as, for example, an ability to catalyze substrate conversion), or may alternatively be primarily active in binding to one or more other molecule. The biological target can be provided in the form of a purified or semi-purified composition, a cell lysate, a whole cell or tissue, or even a whole organism. The level of biochemical activity is detected in the presence of the compound, and a statistically significant change in the biochemical activity, relative to the level of biochemical activity in the absence of the compound, identifies the compound as a modulator, *e.g.* inhibitor or potentiator of the biological activity of the target protein. In some cases, particularly where assays are done on whole cells or organisms, the effect of the chemical compound may be to alter the amount, in addition to or instead of the activity, of the particular biological target. "Modulators", therefore, are chemical compounds that alter the level of activity of a particular target molecule.

21) Please replace the paragraph starting on page 16 line 18 and ending on page 17 line 8 with the following amended paragraph:

021 As discussed above, once a specific desired effect on a biological target has been associated with a particular compound of the inventive library, the compounds of the present invention may be utilized as a therapeutic agent for a particular medical condition. A therapeutic agent for use in the present invention may include any pharmacologically active substances that produce a local or systemic effect in animals, preferably mammals, or humans. The term thus means any substance intended for use in the diagnosis, cure, mitigation, treatment or prevention of disease or in the enhancement of desirable physical or mental development and conditions in